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Biomass: A key source of energy in rural households of Chamarajanagar district

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ABSTRACT

Biomass is the most prominent renewable energy resources. It plays a vital role in meeting the domestic energy needs among the rural households of developing countries. The present study has been made to assess the utilization pattern of fuel sources among the households of five selected villages of Chamarajanagar district. The calorific values of commonly used firewood species have been determined. The results have shown that there is a greater dependency on biomass energy for domestic needs as compared to commercial ones. Firewood is the primary energy source (98.62%) for cooking and heating purposes among the rural households. The investigation has revealed that about half of the households are using different fuel wood species without the awareness of thermal efficiency in their traditional biomass cook stoves. An attempt has been made to investigate the calorific values of the fuel wood species used by them. Based on the findings it has been suggested usage of species with greater heating efficiency with lesser quantity would be sufficient to meet their daily energy requirements

Keywords: Biomass, Cook stove, Chimney, Ventilation, Calorific value.

INTRODUCTION

Energy is the basic unit which plays an important role in socio-economic development of any region. It is widely recognized that energy is linked in numerous ways to the achievement of virtually all Millennium Development Goals (MDGs), in terms of reducing poverty, improving human welfare and raising living standards [1]. Demand of energy requirement is directly proportional to the development rate and population growth rate of the country. The availability of energy source is in the form of renewable and non-renewable energy sources. Among these, biomass is a kind of most promising and alternative renewable energy resources. It includes firewood, agricultural residues, dung and animal waste. This is the main source of energy for rural households for cooking and heating purposes. Biomass demand continued to grow steadily in the heat, power, and transport sectors. Total primary energy consumption of biomass reached approximately 57 exajoules (EJ) in 2013 of which almost 60% was traditional biomass, and the remainder was modern bioenergy (solid, gaseous, and liquid fuels) [2].

India derives the bulk of its cooking energy needs from solid fuels, such as firewood, crop residues or cattle dung [3]. The utilization of biomass as energy source in India is more because, about 70% of people are living in rural areas. Moreover, traditional energy sources such as biomass account for over 26% of India’s total primary energy consumption. That is more than India’s consumption of oil, which stands at 24%. Fuel wood is the universal source of energy, accounting for 60% of the total fuel requirement in rural India [4]. Rao and Reddy [5] reported that socio-economic factors have strong influence on choice of households energy sources in India.

Women and children are mainly involved in collection and combustion of firewood and are thus highly exposed to biomass smoke. Biomass smoke contains many noxious components, including respirable suspended particulates, carbon monoxide, nitrogen oxides, formaldehyde, and polyaromatic hydrocarbons, such as benzo[α]pyrene. High exposures to these pollutants in indoor environment can cause serious health problems [6, 7, 8]. The levels of these pollutants mainly depend on the cook stoves, fuels and housing pattern (ventilation). Cooking areas in many households are poorly ventilated, and about one-half of all households do not have a separate kitchen [9].

Cook stoves used by the rural households are very simple and are not properly designed to remove biomass smoke particles during combustion process. This has lead to reduction in the thermal efficiency as well as their high exposure to high levels of indoor air pollutants. In developing countries, such as India, daily air pollution exposures from cooking with biomass typically exceed relevant health based guidelines by factors of 20 or more [10]. In view of this the present investigation was carried out to assess the utilization pattern of biomass energy resources in five villages of Chamarajanagar district.

MATERIALS AND METHODS

The study was carried out in five villages namely Chandakavadi, Kethanahalli, Sampigepura, Baragi and Kadabur of Chamarajanagar district, Karnataka. It is located at $11^0\ 40'$ to $12^0\ 48'$ North latitude and $74^0\ 52'$ to $76^0\ 07'$ East longitude. This district has geographical area of 5676 Sq. Kms comprising a population of about 10,20,962. Random sampling of households was made for collecting the data and information on several household parameters by personal interviews. The survey was conducted to identify and quantify the fuel sources and their utilization pattern in the households. A questionnaire was designed to collect the data pertinent to socio-economic conditions, fuel sources, housing characteristics and type of cook stoves used by the households.

Determination of Calorific value:
The commonly used firewood species by the households were collected and processed for determination of its calorific values. One gram of the wood powder was oven dried to constant weight and burned in an oxygen bomb calorimeter (Model AC 350) for finding the calorific value.

RESULTS AND DISCUSSION

Socio-economic characteristics of households surveyed in five villages are shown in Table 1. Among the respondents 62 % are females and 38% are males; while 66 % are illiterates and 34% are literates. From this it is evident that the literacy rate is low in these villages. Based on the landholdings of the respondents the households are categorized as landless or low (below 1 acre), middle (1-5 acre) and high (above 10 acre). Among these, 24% of households posses land below 1 acre, 34 % have 1-5 acres, 1% with more than 10 acres and 41% of households are landless. The households are classified into four types based their economic status as; low (Rs.1,000-Rs.10,000), middle (Rs.11,000-Rs.50,000), high (>Rs.50,000) and without income. Among these villages most of the households (42.3%) come under the category of low income level while 26% of the households have no fixed income. Households with low, middle and without income groups are mainly dependent on biomass energy sources.

Table 1: Socio-economic characteristics of rural households

Name of the villages	Socio-economic characteristics											
	Gender		Literacy (%)		Land holdings (%)				Income (%)			
	Male	Female	Literate	Illiterate	Nil	Low	Medium	High	Nil	Low	Medium	High
Chandakavadi	263	522	43.3	56.7	48	37.3	13.7	1	51	28	20	1
Kethanahalli	100	44	31.7	68.3	24.75	25.75	47.5	2	10.9	33.7	51.5	3.9
Sampigepura	32	51	39.4	60.6	8.45	28.17	61.97	1.41	11.3	57.7	22.5	8.5
Bargai	191	374	50.4	49.6	27	26.6	46	0.4	9.3	63.7	23.8	3.2
Kadabur	38	24	4.8	95.2	97.6	2.4	0	0	47.6	28.4	24	0

***Landholdings** - low < 1acre, middle – 1-5 acre, high > more than 10 acre. **Income**- - low (Rs.1,000-10,000), middle (Rs. 10,000-50,000), high >Rs. 50,000. **Nil**- Landless /without income.*

Table 2 presents the type of energy sources used as fuel for domestic purposes. The results have shown that firewood is the primary and dominant energy source for their daily requirement. The households use four types of energy sources such as firewood, agricultural residues, kerosene and liquid petroleum gas (LPG) for cooking and heating purposes. Among the villages investigated, 100% of firewood utilization was recorded at Kethanahalli, Sampigepura and Kadabur. The study revealed that there were no LPG users in Kadabur as it is noticed that 47.6% of households have no income. This clearly indicates that there is a strong correlation between the choice of fuel source and income status. The usage of commercial energy sources such as kerosene and LPG found to be 15.2% and 34.4% respectively. It was evident from the studies that biomass was the major energy source for households as compared to conventional energy sources.

Table 2: Type of energy sources used as fuel for domestic purposes by the households (%)

Name of the villages	Energy sources			
	LPG	Kerosene	Firewood	Agricultural residues
Chandakavadi	29.6	37	94.7	51.8
Kethanahalli	15.8	5	100	82.2
Sampigepura	43.7	11.3	100	88.7
Bargai	82.7	20.2	98.4	72.6
Kadabur	0	2.4	100	21.4
Mean	34.4	15.2	98.6	63.3

The trees commonly used as firewood by the people and their calorific values are shown in Table 3. A total of 15 species belonging to 9 families were identified which are commonly used as fuel wood. Calorific value is an important parameter to assess the combustibility of any flammable material. The results have shown that, calorific value of firewood species ranged between 2847 to 7189 cal/gm. *Casuarina equisetifolia* has shown highest (7189 cal/gm) calorific value while *Syzygium cumini* showed lowest calorific value. The wood of most species of *Casuarina* is heavy, dense and very hard. The casuarinas produce high quality of fuel wood and charcoal, the wood is easily split and has low ash content. It makes an excellent fuel wood, producing good heat while being relatively smokeless and has been called 'the best firewood in the world'. It burns readily even when green and makes exceptionally fine charcoal [11]. The density of wood is 900-1000 kg/m^3.

The quantity and time involved in collection of firewood and its consumption per household are shown in Table 4. The people used to travel a distance of 1.5 km to 2 kms for collection of firewood. The time spent to collect fuel wood on an average of 29 kg per day was around 2 hrs. It is recorded that on an average 4.2 kg of firewood is consumed per household per day. The consumption level of firewood is all most similar in Chandakavadi, Kethanahalli, Baragi and Kadabur except in Sampigepura. The quantity of firewood utilization by the households mainly depends on type of fuel wood, household size and seasonal conditions.

Table 3: Calorific value of commonly used firewood species

SL. No	Scientific name	Family name	Local Name	Calories/gm
1	*Cocos nucifera*	Arecaceae	Tengu	4898
2	*Ficus benghalensis*	Moraceae	Aala	5784
3	*Tamarindus indica*	Leguminaceae	Hunase	6071
4	*Morinda tinctoria*	Rubiaceae	Maddi	3907
5	*Casuarina equisetifolia*	Casuarinaceae	Suragi	7189
6	*Syzygium cumini*	Myrtaceae	Nerale	2847
7	*Ficus glomerata*	Moraceae	Atti	4781
8	*Artocarpus heterophyllus*	Moraceae	Halasu	5111
9	*Pongamia pinnata*	Leguminosae	Honge mara	4350
10	*Acacia nilotica*	Leguminosae	Gobbali	3800
11	*Thespesia populnea*	Malvaceae	Buguri	3121
12	*Eucalyptus globulus*	Myrtaceae	Neelagiri	3811
13	*Tectona grandis*	Lamiaceae	Thega	4850
14	*Cassia fistula*	Leguminosae	Kakke	4897
15	*Azadirachta indica*	Meliaceae	Bevu	5116

Table 4: Quantity and time involved in collection of firewood by the villagers

Name of the villages	Distance travelled (km)	Time spent / collection (hr)	Firewood collection/day (kg)	Firewood consumption/ Household/day (in kg)
Chandakavadi	2	1	30	4.3
Kethanahalli	2	2	27	4
Sampigepura	1.6	1.8	26	3.82
Bargai	1.7	2	29.9	4.6
Kadabur	1.5	2.5	32.5	4.5
Mean	1.8	1.9	29	4.2

Table 5: Type of biomass cook stoves used by the households

Name of the villages	Type of cook stoves used by households (In Percentage)			
	Traditional	Clay	Metal	Astra
Chandakavadi	3.52	44.4	3.2	41
Kethanahalli	17.8	29.7	14.85	37.6
Sampigepura	3	15.5	1.22	80.28
Bargai	3	22.6	3	68
Kadabur	33.3	45	21.7	0
Mean	12	31	8.8	45.4

The different types of biomass cook stoves used by the households in these villages are shown in Table 5. People use four types of cook stoves for biomass fuels such as traditional, clay, metal and Astra. Among these stoves Astra is considered as an improved cook stove because it is designed to capture maximum heat along with a chimney to remove suspended particulate matter generated during combustion. This type of cook stove is used by 45.4% of the households followed by clay (31%), traditional (12%) and metal (8.8%) stove. During the study it was recorded that no households used Astra stove in Kadabur village as they exclusively depend on clay stoves. This may be because of the cost of Astra stove which is costlier to clay stove. The traditional stove is made up of three stones which consume more firewood with much loss of heat as compared to other stoves.

Table 6: Housing pattern and location of cook stoves in the households

Name of villages	Housing pattern				Location of cook stove		
	Chimney without ventilation	Chimney with ventilation	No chimney and no ventilation	Ventilation without chimney	Outside of the house	Living area	Separate kitchen
Chandakavadi	6.34	41.55	18	34.11	13.7	24.3	62
Kethanahalli	16.8	52.5	1	29.7	2	8	90
Sampigepura	0	85.9	0	14.1	1.4	4.2	94.4
Baragi	3.6	87.2	6	3.2	4.4	12.5	83.1
Kadabur	7.14	28.6	4.76	59.5	2	90.86	7.14
Mean	7	59	6	28	5	28	67

The cooking area and housing pattern were found to be different among the households (Table 6). Most of the households cook at separate kitchen while others cook in living room and outside the house. It was observed that 67% of households used to cook exclusively in separate kitchen. The results have shown that only 59% of houses are having good ventilation and chimney. The ventilation and chimney are most important characteristics which help in reduction of indoor air pollutants. Opened door and window in a kitchen lowered the particulate matter (PM) 1-hour concentration between 93 to 98% as compared to closed kitchen [12].

CONCLUSION

The results of the investigation have revealed that there is a greater dependency on biomass energy sources in the rural households of Chamarajanagar. Commonly available firewood species are being randomly used as fuel wood by the households without knowing the thermal efficiency. A poorly designed biomass cook stove is mainly used for cooking and heating processes. This is because of socio-economic constraints involving affordability to purchase improved cook stoves, lack of awareness/willingness to shift from the traditional practice to recent technologies for cleaner fuels. The determination of calorific values of fuel wood species can aid in identification of suitable species for better utilization of biomass energy. Recommendation of growing such species in wastelands of their vicinity helps in promoting self-sustenance so as to provide better security in supply of energy sources.

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